AIRCRAFT REPORTS OF CIRRIFORM CLOUDS ON CERTAIN HIGH LATITUDE ROUTES AND CALIFORNIA TO HONOLULU

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ABSTRACT

Special high-level cloud observations from two commercial jet air lines are used to estimate the vertical distribution of cirriform clouds. One year's data are summarized graphically for certain high-latitude routes and the California-Honolulu sector. Tropopauses in very high latitudes are occasionally exceeded in height by cirrus. Tropical tropopause levels are consistently 5 km. or more above the cirrus tops reported between Honolulu and the California coast.

1. INTRODUCTION

The climatic distribution of cirriform clouds has materialized slowly, especially in its vertical dimension. In the past few decades, millions of high cloud observations have been made from the ground, but with large errors and biases. Double-theodolite reports during the International Cloud Year of 1896–1897 [11] were relatively accurate but biased because of lower obscuring cloudiness and nocturnal viewing difficulties.

The employment of aircraft as observation platforms clearly reduces the errors of ground observations and contributes to the statistical basis for a more complete cloud climatology. Some previous data-gathering programs involving aircraft have taken place in Canada (Clodman [4]), the United States (Appleman [2]), England (James [7], Murgatroyd and Goldsmith [8]), and Western Europe (Alt [1]). More recently, Bertoni [3] reported upon a 15-mo. period of data collection over more than half of the Northern Hemisphere, obtaining probabilities of clear lines of sight at various viewing angles. The data presented here represent an extension of these programs to other geographical regions.

2. DATA SOURCES AND ERRORS

For this study, high-level cloud reports from the jet aircraft of two commercial carriers were entered on a special form by the flight crews. The form permitted the recording of "time, altitude, position, weather conditions at flight level, estimated altitudes of clouds above flight level—base and top—and estimated altitude of cloud tops below flight level." Estimates of coverage were not requested, thus maintaining simplicity and hopefully enhancing the cooperation of the pilot-observers.

Carrier One operates along high-latitude airways between Copenhagen and Anchorage or Los Angeles (fig. 1), occasionally passing over the North Pole. Reports were requested from this carrier at the top of climbout westbound from Søndre Strømfjord, Greenland, e.g., over Davis Strait, and inflight upon crossing 50°N., 60°N., and 70°N., as well as when abeam of Iceland and near the Pole. Carrier Two connects Los Angeles and San Francisco with Honolulu, and the flight crews were asked to choose two reporting points per trip. As pointed out by Clodman [4] in his discussion of bias in aircraft cloud reports, this freedom of choice probably introduces a bias in favor of the overestimation of occurrences. A mean flight level of about 10 km. was typically selected on all of the routes under consideration.

3. DISTRIBUTION OF CIRRUS, CARRIER ONE

Cumulative frequency of clouds above specified altitudes was chosen for the graphical representation of results. Carrier One, reporting from August 1965 to August 1966, had the overall frequencies of occurrence shown in figure 2. The curve for Davis Strait represents the climbout data for Søndre Strømfjord and is not confined to ice-crystal clouds. The other four curves give the observed cirrus distributions at the other reporting points. As may be noted in figure 1, the crossing of parallels at 50°N., 60°N., and 70°N. occurs at a fairly wide band of longitudes. Clodman's data [4] are largely from 45°N. to 50°N. over Canada, and are found to agree very well with the curve for 50°N.

The Polar Zone (fig. 3) has an appreciably greater cirrus coverage in summer, but the type of data form used does not permit identification of the cause as "convective activity," specifically. Here the amount of daylight is sufficient in all seasons for reliable cloud observations, thus ruling out the possible diurnal bias present in the other sectors. A second location with a particularly interesting seasonal variation is Davis Strait (fig. 4). Although few cirrus were seen over Davis Strait above 10 km. in

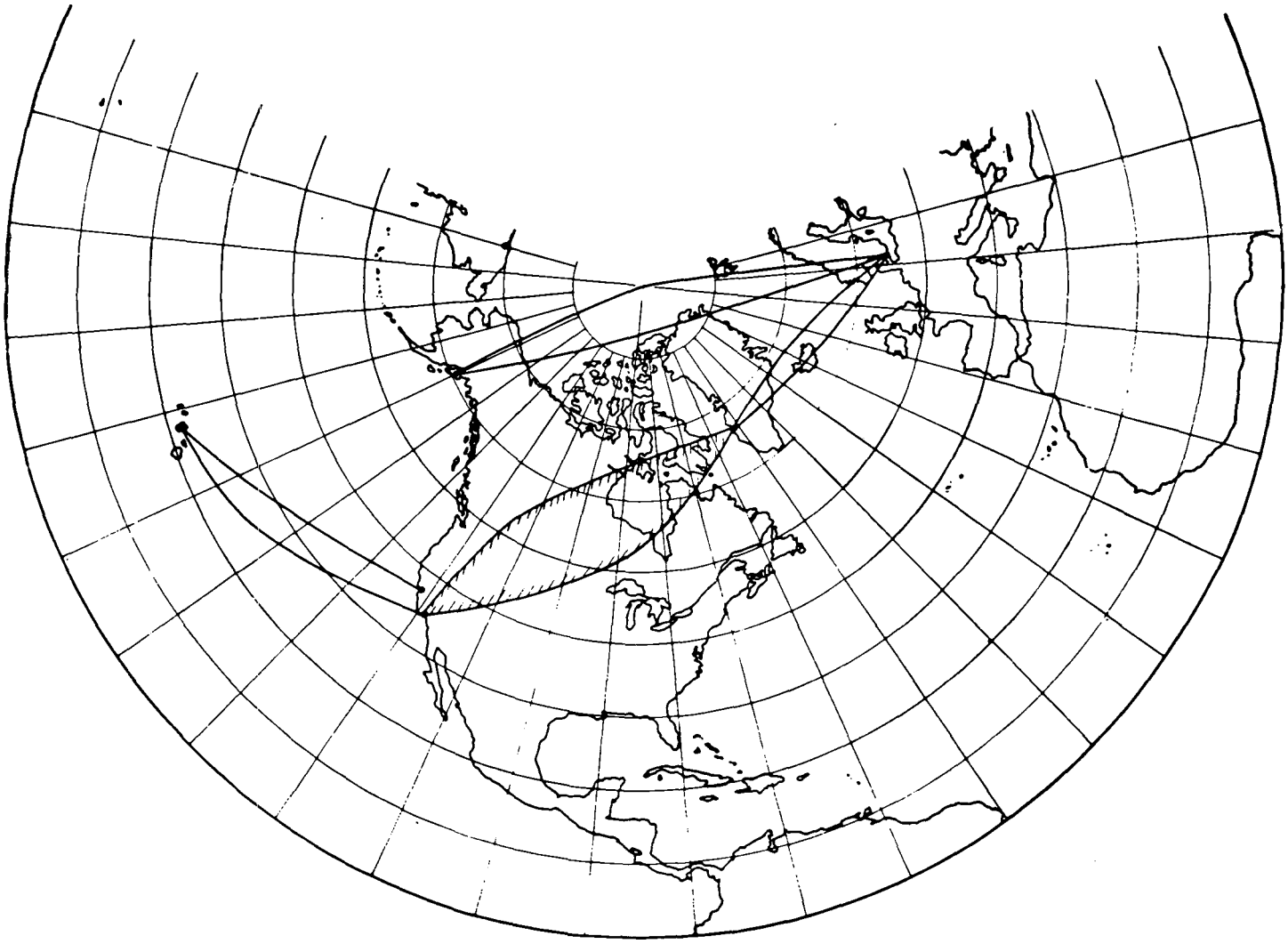

FIGURE 1.—Routes of participating commercial air lines. Carrier One operates at high latitudes in the Western Hemisphere; Carrier Two operates over a portion of the Pacific Ocean. The hatched lines are an envelope of alternate routes.

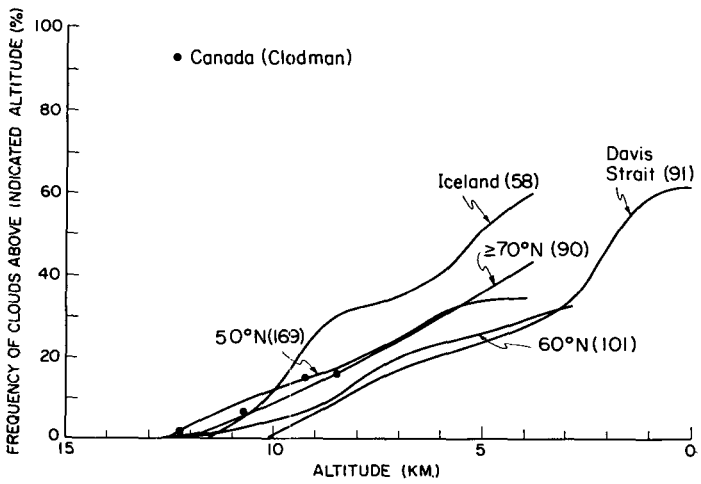

FIGURE 2.—Cumulative vertical distribution of cirriform clouds during 1 yr. over Davis Strait, near Iceland, within 20° of the North Pole, and at 50°N. and 60°N. Numbers of cases are in parentheses. Dots are for Clodman's data [4] in southern Canada.

any season, the curves for summer and fall show rapidly increasing frequencies of occurrence of clouds, including non-cirrus types, with decreasing altitude below this level.

During processing of the aircraft reports from the Arctic, it was noted that nearly half of the clouds observed above 4 km. were above the mean tropopause heights. Therefore, radiosonde data tabulations were obtained for January–May 1966 to compare individual tropopause heights with estimated cloud tops. This comparison indicated that cirrus clouds were being observed in the stratosphere an average of once per month. Since but 1 day in 4 had an observation in this region, the occurrence rate in the stratosphere near the Pole was a few times per month during this limited period. The lower stratosphere was essentially isothermal in these cases.

4. DISTRIBUTION OF CIRRUS, CARRIER TWO

The collection of 12 mo. of data from Carrier Two goes from April 1965 to the end of 1966, with gaps. The over-

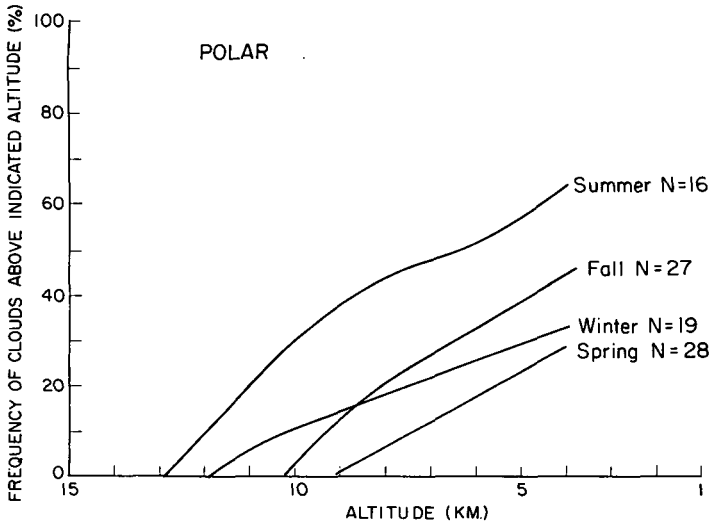

FIGURE 3.—Seasonal cumulative vertical distribution of clouds above 4 km. at latitudes ≥70°N. during 1 yr. N=number of cases.

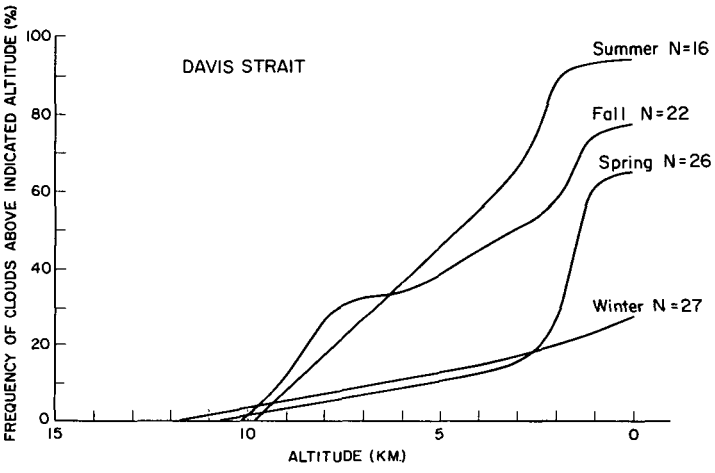

FIGURE 4.—Seasonal cumulative vertical distribution of clouds over Davis Strait during 1 yr. N=number of cases.

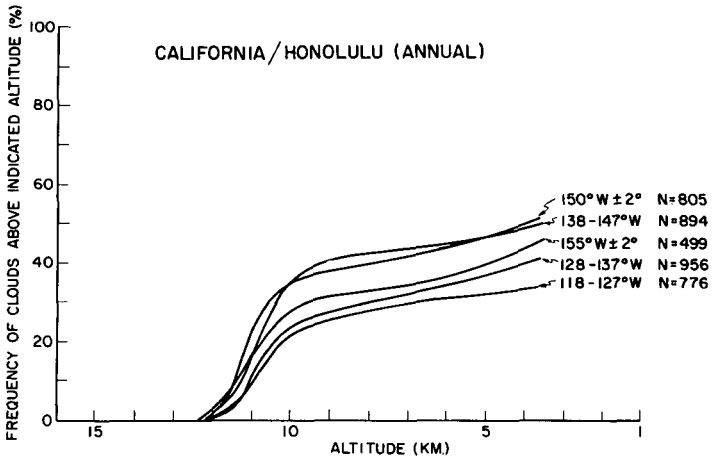

FIGURE 5.—Cumulative vertical distribution of clouds above 4 km. during 1 yr. within the route sectors indicated. N=number of cases.

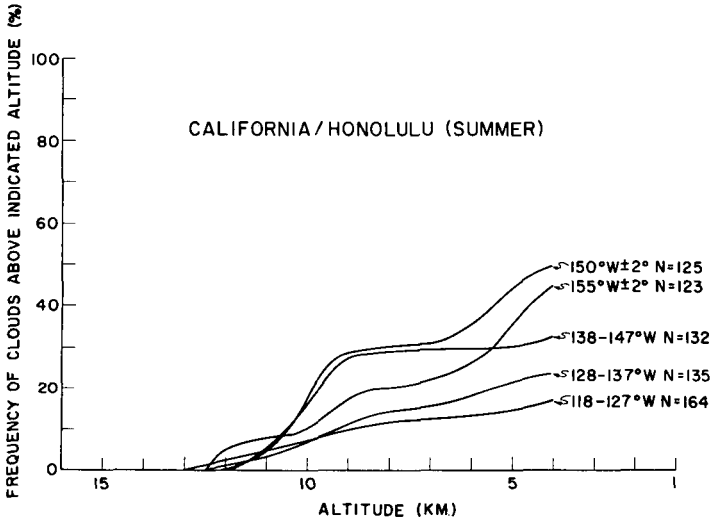

FIGURE 6.—Cumulative vertical distribution of clouds above 4 km. during summer (June–August) within route sectors indicated. N=number of cases.

all results show (fig. 5) a general increase in cirriforms westward from the coast of California. A similar chart for summer (fig. 6) gives some evidence of a peak in cirrus occurrence east of Honolulu, near the location of a north-south, horizontal shear line in the mean flow at cirrus levels, according to Crutcher [5]. The number of observations, N, indicates that two or three flights made reports each day within each of the five route segments.

Project Cloud Trail [2], operating in the United States, found a mean cirrus height of cloud base of 10 km. in the Southern States. Our result is quite similar, although Carrier Two routes are about 10° nearer the Equator. With the tropical tropopause at 15 to 17 km., a relatively cloud-free layer of 5-km. depth again appears between cirrus tops and this tropopause, suggesting a persistent subsidence. As the observations were made from a vantage point near 10 km. the observing error should be minimal. A previous study of the same kind on routes between 10°N. and 35°S. by the author reported in [6] shows a similar cloud-free layer which is almost as deep, excepting within active Intertropical Convergence Zones. The mean position of such zones is at least 15° lat. south of the Carrier Two routes.

5. CONCLUDING REMARKS

The compendium on cirrus prepared by Stone [10] summarizes the studies on cirrus distribution made prior to 1957. Since then, a very limited quantity of data has been reported upon, although commercial jet aircraft have observed meteorological conditions from an altitude

of 10 to 12 km. This paper has given the results of a year's special reporting by flights over high-latitude airways and between Honolulu and the California coast. To progress more rapidly with cirrus height measurements on a global scale, new satellite-observing techniques utilizing the clouds' reflected solar radiation in the oxygen "A" band (Saiedy, Hilleary, and Morgan [9]; Wark and Mercer [12]) may be feasible.

ACKNOWLEDGMENTS

This paper has as its data source the special reports prepared inflight by aircraft crew members of Scandinavian Airways System and United Air Lines. The cooperation of these personnel and their supervisors is gratefully acknowledged. Financial support was provided by NASA, under Contract NASr-54(08).

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[*Received February 14, 1968; Revised April 24, 1968*]